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(54) **COMBUSTOR PANELS HAVING ANGLED RAIL**

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F23R 3/06 (2006.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,548,485 A * 4/1951 Lubbock F23M 5/085 29/889.2
3,956,886 A * 5/1976 Sedgwick F23R 3/007 60/753

(Continued)

FOREIGN PATENT DOCUMENTS

DE 10158548 6/2003
EP 3056813 8/2016

OTHER PUBLICATIONS

European Search Report, European Application No. 16203761.8, dated Jun. 28, 2017, European Patent Office; European Search Report 9 pages.

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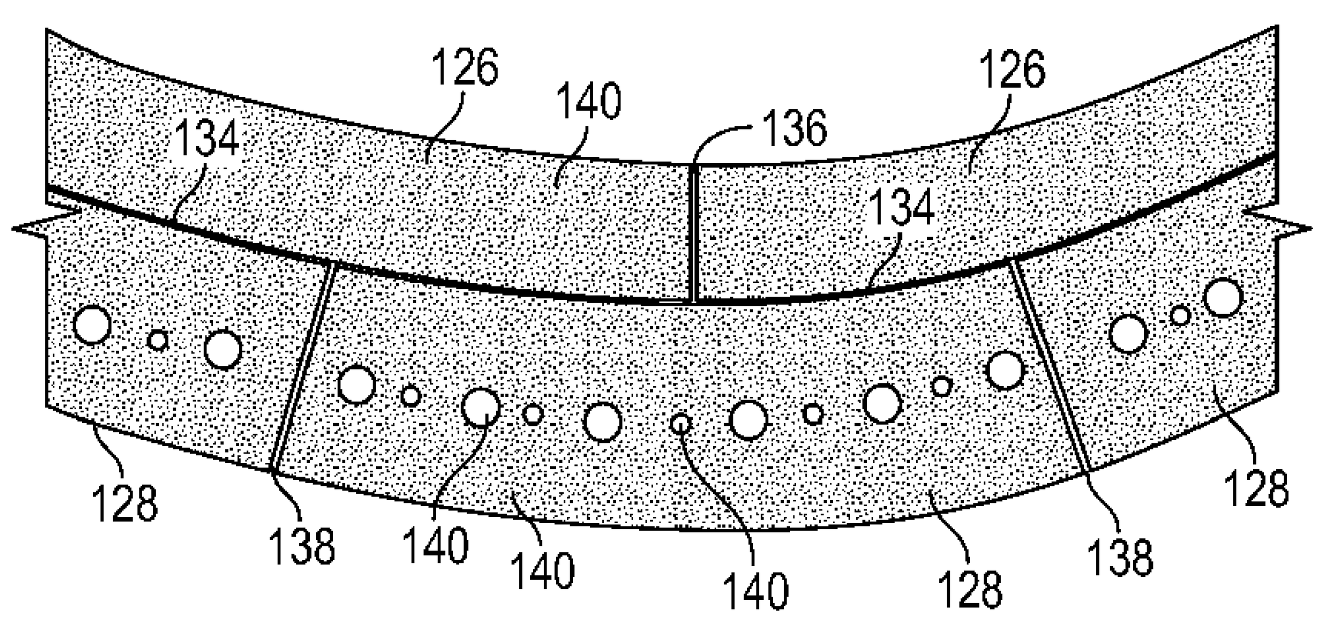
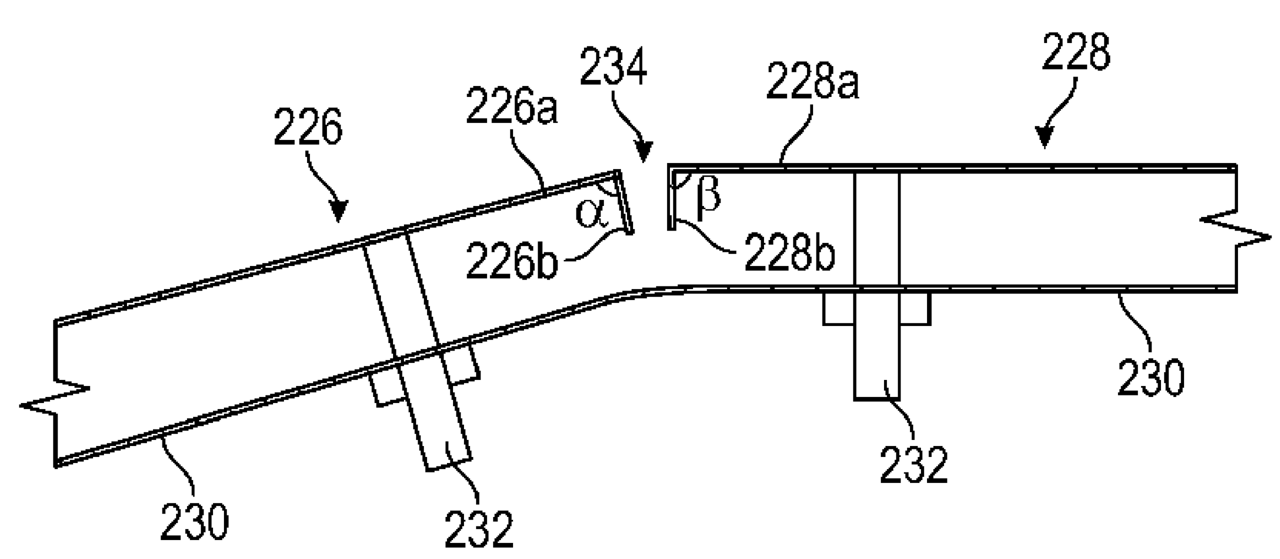
(57) **ABSTRACT**

A combustor of a gas turbine engine including a combustor shell having an interior surface defining a combustion chamber, a first panel mounted to the interior surface at a first position, the first panel having a first surface and a first rail extending from the first surface toward the combustor shell, the first rail configured at a first angle relative to the first surface, and a second panel mounted to the interior surface at a second position axially adjacent to the first panel, the second panel having a second surface and a second rail extending from the second surface toward the combustor shell, the second rail configured at a second angle relative to the second surface. The first and second rails are proximal to each other and define a circumferential gap there between and at least one of the first or second angles is an acute angle.

12 Claims, 4 Drawing Sheets





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(56) **References Cited**

U.S. PATENT DOCUMENTS

5,079,915	A *	1/1992	Veau	F02K 1/822 60/753
5,396,759	A *	3/1995	Richardson	F23R 3/002 60/756
5,636,508	A *	6/1997	Shaffer	F23R 3/007 60/753
6,029,455	A *	2/2000	Sandelis	F23R 3/002 60/752
6,408,628	B1 *	6/2002	Pidcock	F23R 3/002 60/752
6,973,419	B1	12/2005	Fortin et al.	
7,140,185	B2 *	11/2006	Burd	F23M 5/085 60/752
7,464,554	B2 *	12/2008	Cheung	F23R 3/00 60/754
8,167,558	B2 *	5/2012	Liang	F01D 5/187 415/115
9,423,129	B2 *	8/2016	Graves	F23R 3/002
9,651,258	B2 *	5/2017	Graves	F23R 3/002
2010/0095679	A1 *	4/2010	Rudrapatna	F23R 3/005 60/752
2011/0005233	A1 *	1/2011	Sadig	F23R 3/04 60/754
2014/0250894	A1 *	9/2014	Petty, Sr.	F23R 3/60 60/754
2015/0330633	A1 *	11/2015	Graves	F23R 3/002 60/753
2016/0238247	A1 *	8/2016	Staufer	F23R 3/002
2017/0176005	A1 *	6/2017	Rimmer	F23R 3/002

* cited by examiner

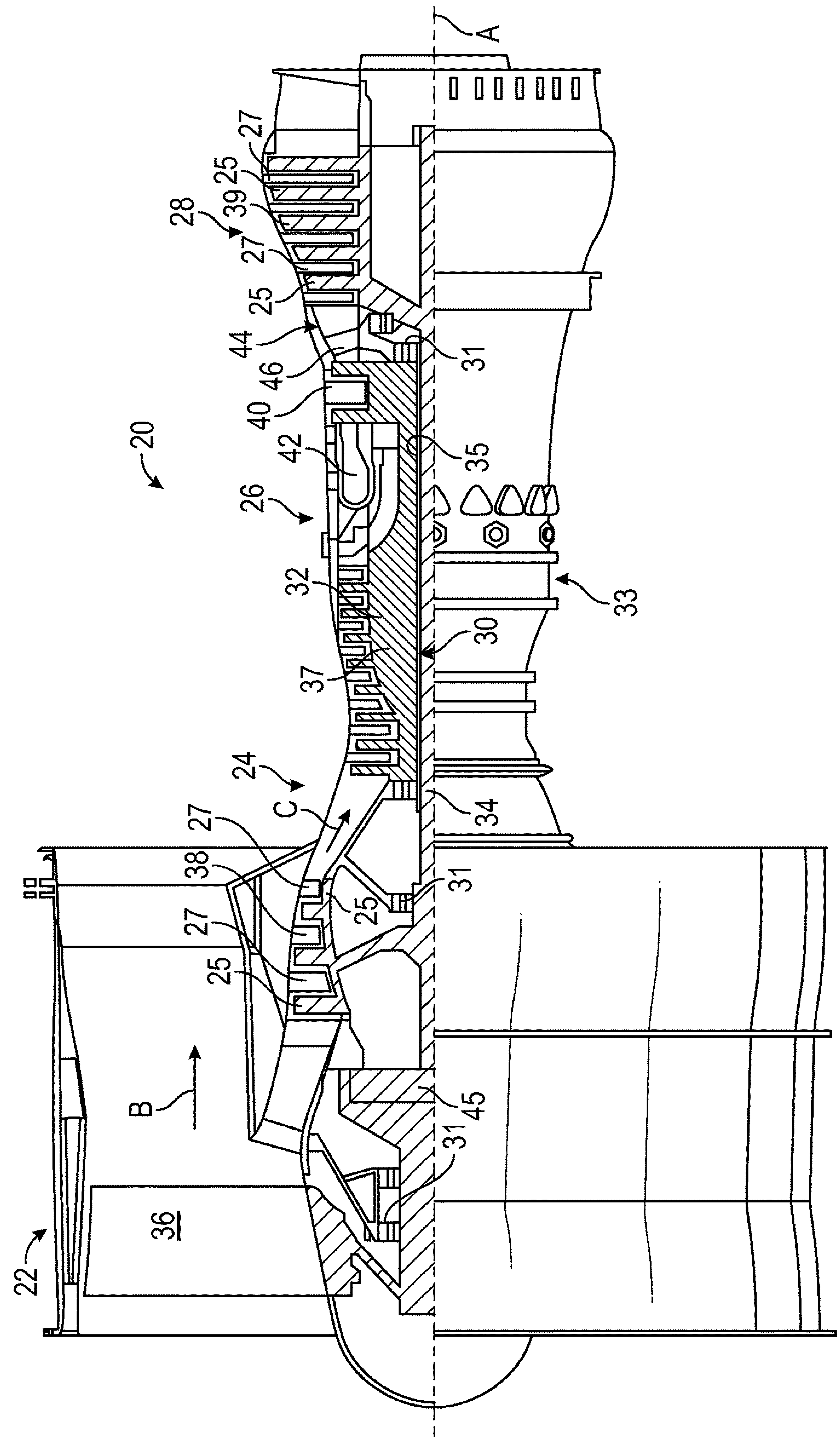
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FIG. 1A

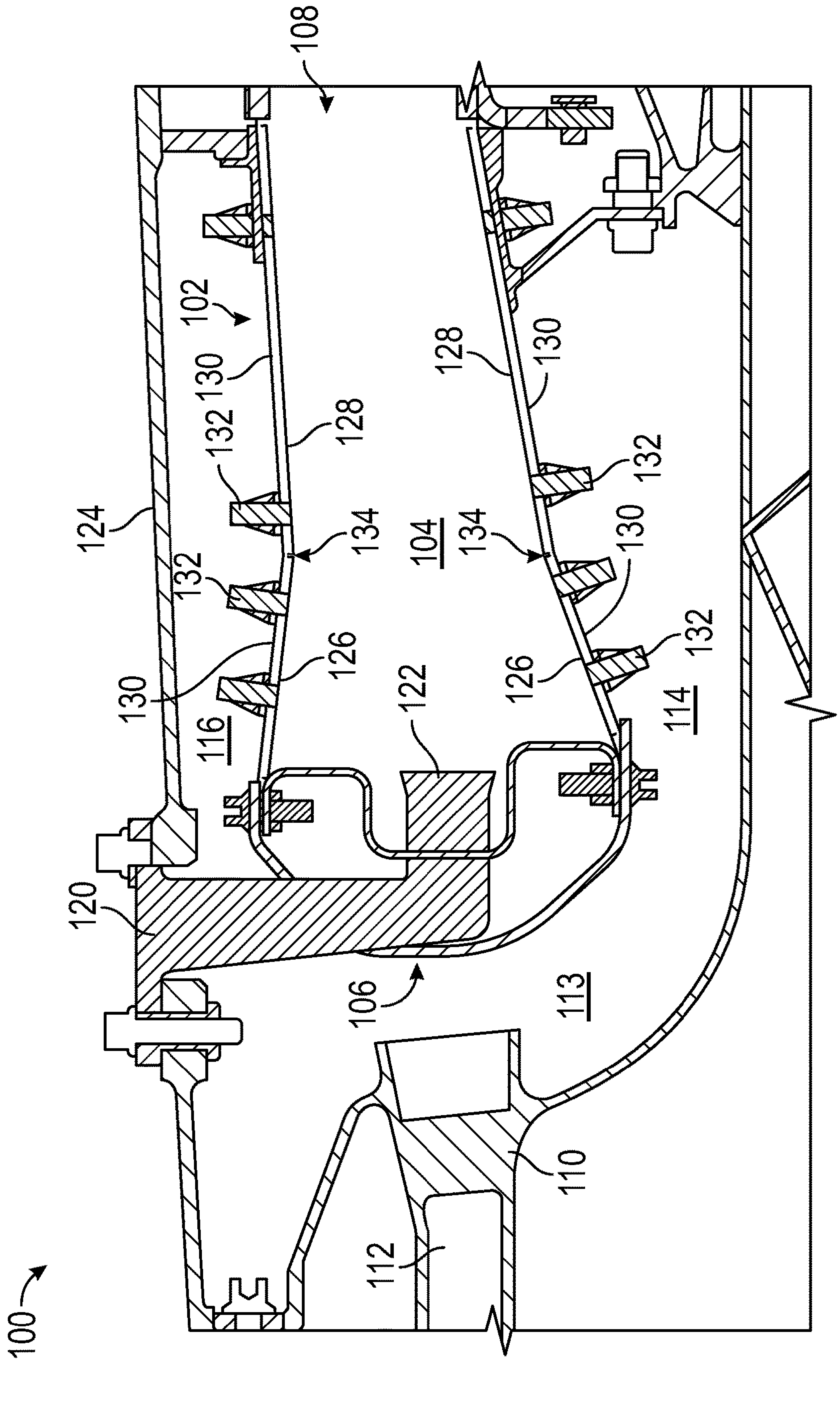
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FIG. 1B

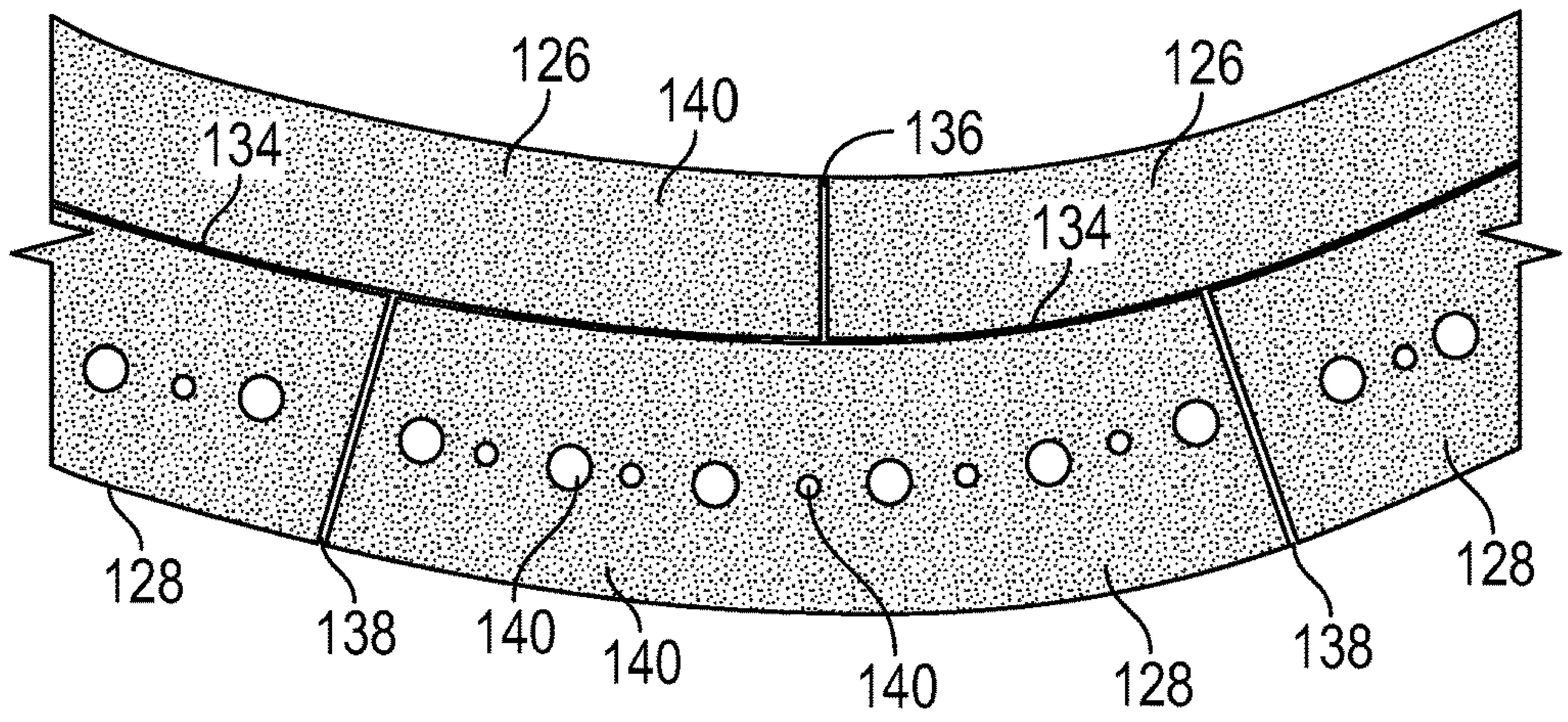


FIG. 1C

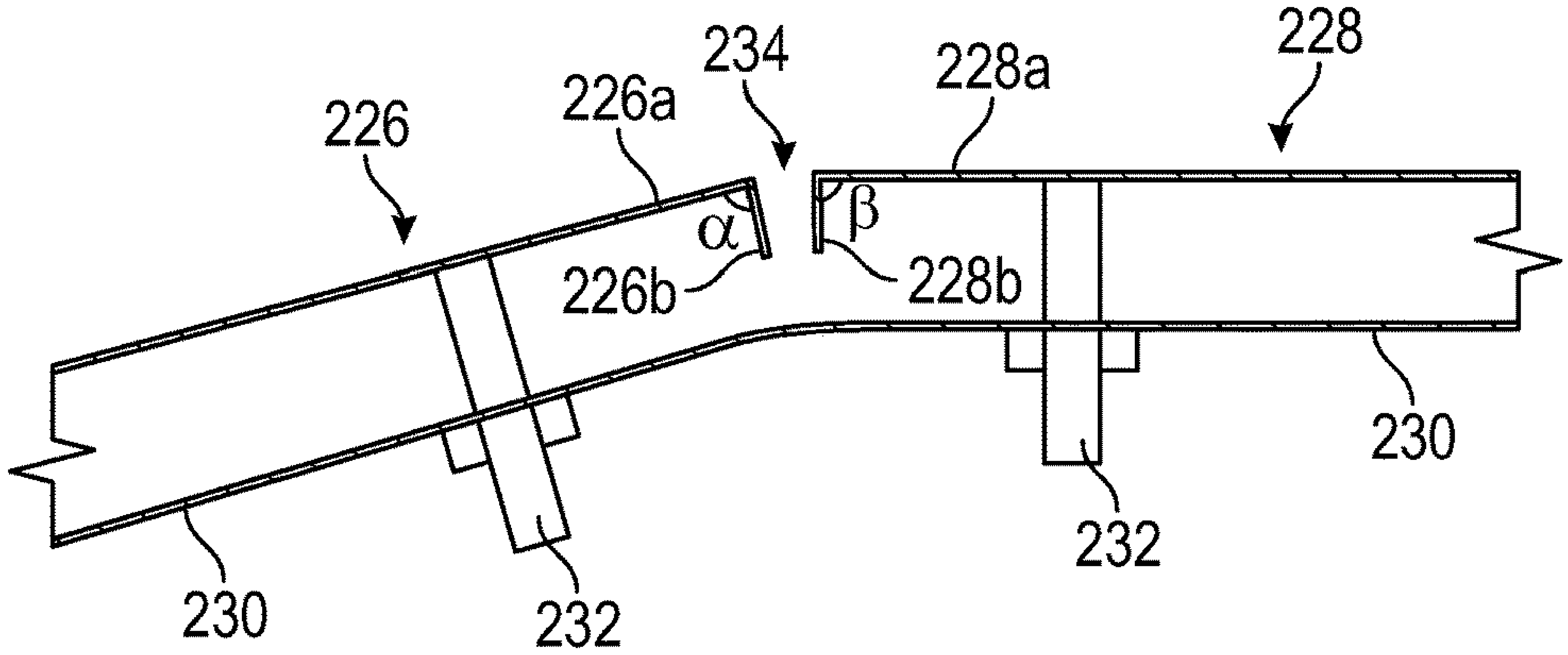


FIG. 2

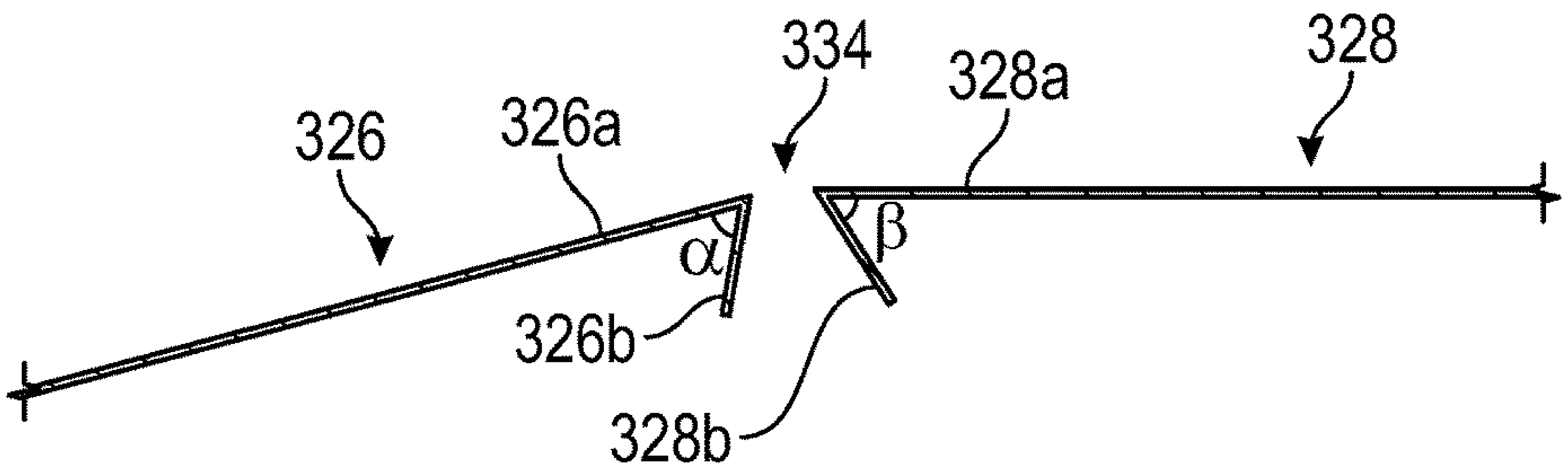


FIG. 3

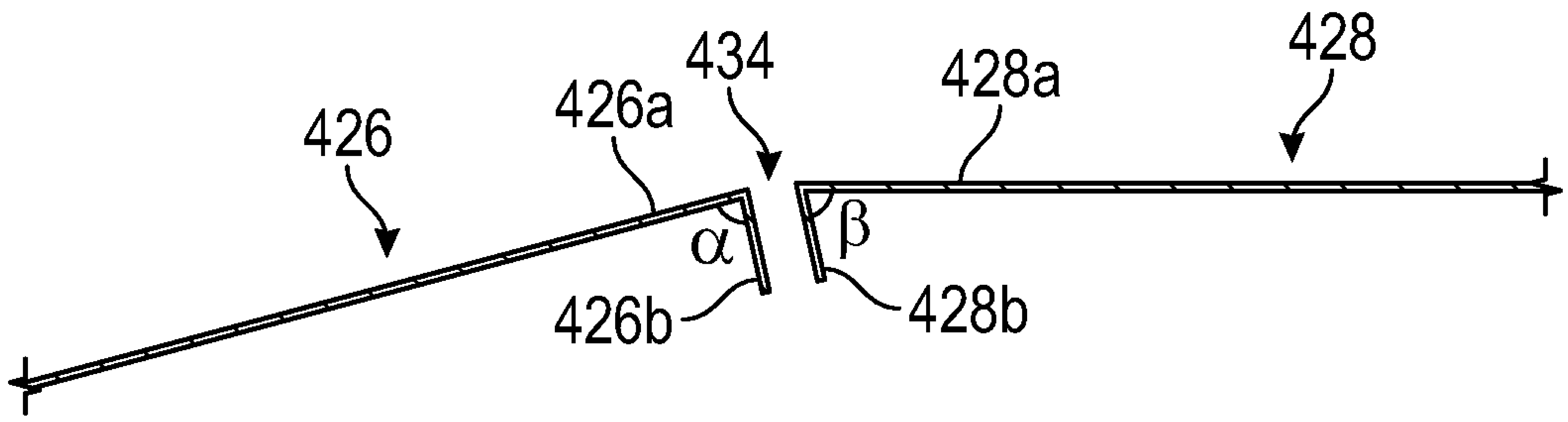
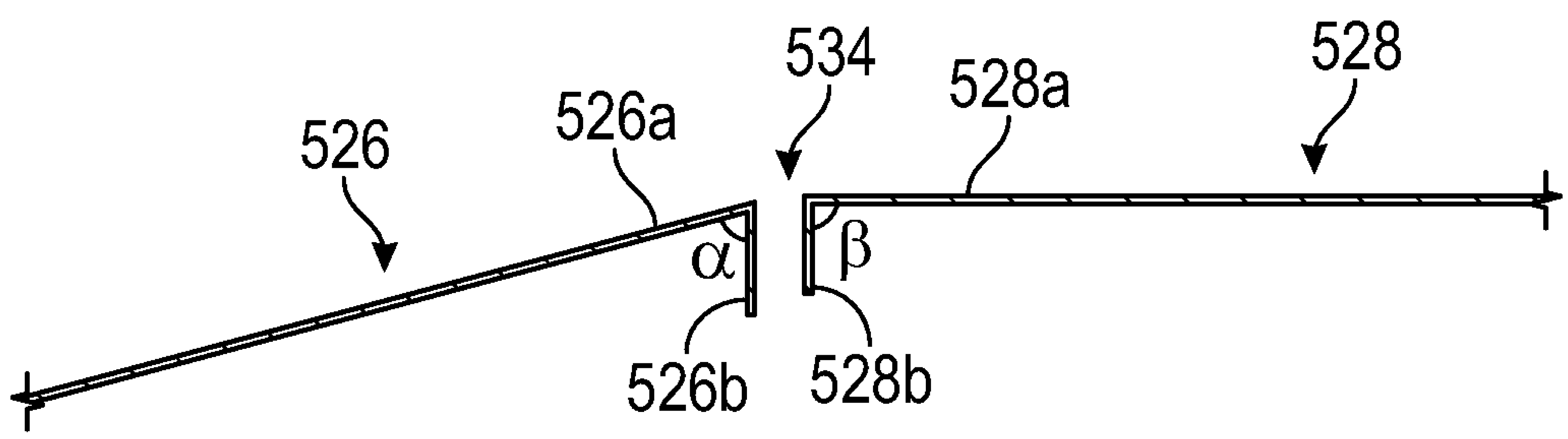

426
426a
434
428a
428
α
β
426b
428b

FIG. 4


526
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534
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FIG. 5

COMBUSTOR PANELS HAVING ANGLED RAIL

BACKGROUND

The subject matter disclosed herein generally relates to panels for combustors and, more particularly, to panels for combustors having angled rails.

A combustor of a gas turbine engine may be configured and required to burn fuel in a minimum volume. Such configurations may place substantial heat load on the structure of the combustor. Such heat loads may dictate that special consideration is given to structures which may be configured as heat shields or panels configured to protect the walls of the combustor, with the heat shields being air cooled. Even with such configurations, excess temperatures at various locations may occur leading to oxidation, cracking, and high thermal stresses of the heat shields or panels. As such, impingement and convective cooling of panels of the combustor wall may be used. Convective cooling may be achieved by air that is trapped between the panels and a shell of the combustor. Impingement cooling may be a process of directing relatively cool air from a location exterior to the combustor toward a back or underside of the panels. Leakage of impingement cooling air may occur through or between adjacent panels at gaps that exist between the panels. However, ingestion of air from the combustor (e.g., hot air) may be forced through the gap, which may lead to increased thermal stresses at the gap.

SUMMARY

According to one embodiment, a combustor of a gas turbine engine is provided. The combustor includes a combustor shell having an interior surface and defining a combustion chamber having an axial length, at least one first panel mounted to the interior surface at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail configured at a first angle relative to the first combustion chamber surface, and at least one second panel mounted to the interior surface at a second position and axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail configured at a second angle relative to the second combustion chamber surface. The first rail and the second rail are proximal to each other and define a circumferentially extending gap there between, and at least one of the first angle or the second angle is an acute angle.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that both of the first angle and the second angle are acute angles.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that the first rail and the second rail are parallel to each other.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that the at least one first panel comprises a plurality of first panels, wherein the plurality of first panels define at least one axially extending gap between two circumferentially adjacent first panels.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that two circumferentially adjacent first panels each have respective axially extending rails that extend from the first combustion chamber surface toward the interior surface, wherein one rail of the axially extending rails is configured at an acute angle relative to the first combustion chamber surface.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that the at least one second panel comprises a plurality of second panels, wherein the plurality of second panels define at least one axially extending gap between two circumferentially adjacent second panels.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that two circumferentially adjacent second panels each have respective axially extending rails that extend from the second combustion chamber surface toward the interior surface, wherein one rail of the axially extending rails is configured at an acute angle relative to the second combustion chamber surface.

In addition to one or more of the features described above, or as an alternative, further embodiments of the combustor may include that the other of the at least one of the first angle and the second angle is configured at a 90° angle.

According to another embodiment, a gas turbine engine is provided. The gas turbine engine includes a combustor including a combustor shell having an interior surface and defining a combustion chamber having an axial length, at least one first panel mounted to the interior surface at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail configured at a first angle relative to the first combustion chamber surface, and at least one second panel mounted to the interior surface at a second position and axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail configured at a second angle relative to the second combustion chamber surface. The first rail and the second rail are proximal to each other and define a circumferentially extending gap there between, and at least one of the first angle or the second angle is an acute angle.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that both of the first angle and the second angle are acute angles.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that the first rail and the second rail are parallel to each other.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that the at least one first panel comprises a plurality of first panels, wherein the plurality of first panels define at least one axially extending gap between two circumferentially adjacent first panels.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that two circumferentially adjacent first panels each have respective axially extending rails that extend from the first combustion chamber surface toward the

interior surface, wherein one rail of the axially extending rails is configured at an acute angle relative to the first combustion chamber surface.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that the at least one second panel comprises a plurality of second panels, wherein the plurality of second panels define at least one axially extending gap between two circumferentially adjacent second panels.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that two circumferentially adjacent second panels each have respective axially extending rails that extend from the second combustion chamber surface toward the interior surface, wherein one rail of the axially extending rails is configured at an acute angle relative to the second combustion chamber surface.

In addition to one or more of the features described above, or as an alternative, further embodiments of the gas turbine engine may include that the other of the at least one of the first angle and the second angle is configured at a 90° angle.

According to another embodiment, a method of manufacturing a combustor of a gas turbine engine is provided. The method includes mounting at least one first panel to an interior surface of a combustion chamber shell at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail configured at a first angle relative to the first combustion chamber surface and mounting at least one second panel to the interior surface at a second position axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail configured at a second angle relative to the second combustion chamber surface. The first rail and the second rail are proximal to each other and define a circumferentially extending gap there between, and at least one of the first angle or the second angle is an acute angle.

In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include that both of the first angle and the second angle are acute angles.

In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include that the first rail and the second rail are parallel to each other.

In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include that the other of the at least one of the first angle and the second angle is configured at a 90° angle.

Technical effects of embodiments of the present disclosure include panels of a combustor that are configured to minimize gaps between adjacent panels such that ingested gas is minimized from flow from a combustion chamber outward through the gaps. Further technical effects include angled rails of panels of a combustor of a gas turbine engine, wherein the angling enables minimization of a gap formed between two adjacent panels.

The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, the following description and drawings are intended to be illustrative and explanatory in nature and non-limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter is particularly pointed out and distinctly claimed at the conclusion of the specification. The foregoing and other features, and advantages of the present disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1**A is a schematic cross-sectional illustration of a gas turbine engine that may employ various embodiments disclosed herein;

FIG. **1**B is a schematic illustration of a combustor section of a gas turbine engine that may employ various embodiments disclosed herein;

FIG. **1**C is a schematic illustration of panels of a gas turbine engine that may employ various embodiment disclosed herein;

FIG. **2** is a side view schematic illustration of two adjacent combustor panels;

FIG. **3** is a side view schematic illustration of two adjacent combustor panels in accordance with an embodiment of the present disclosure;

FIG. **4** is a side view schematic illustration of two adjacent combustor panels in accordance with another embodiment of the present disclosure; and

FIG. **5** is a side view schematic illustration of two adjacent combustor panels in accordance with another embodiment of the present disclosure

DETAILED DESCRIPTION

As shown and described herein, various features of the disclosure will be presented. Various embodiments may have the same or similar features and thus the same or similar features may be labeled with the same reference numeral, but preceded by a different first number indicating the figure to which the feature is shown. Thus, for example, element "a" that is shown in FIG. X may be labeled "Xa" and a similar feature in FIG. Z may be labeled "Za." Although similar reference numbers may be used in a generic sense, various embodiments will be described and various features may include changes, alterations, modifications, etc. as will be appreciated by those of skill in the art, whether explicitly described or otherwise would be appreciated by those of skill in the art.

FIG. **1**A schematically illustrates a gas turbine engine **20**. The exemplary gas turbine engine **20** is a two-spool turbofan engine that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26**, and a turbine section **28**. Alternative engines might include an augmenter section (not shown) among other systems for features. The fan section **22** drives air along a bypass flow path B, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26**. Hot combustion gases generated in the combustor section **26** are expanded through the turbine section **28**. Although depicted as a turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to turbofan engines and these teachings could extend to other types of engines, including but not limited to, three-spool engine architectures.

The gas turbine engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine centerline longitudinal axis A. The low speed spool **30** and the high speed spool **32** may be mounted relative to an engine static structure **33** via several bearing systems **31**. It should be understood that other bearing systems **31** may alternatively or additionally be provided.

The low speed spool **30** generally includes an inner shaft **34** that interconnects a fan **36**, a low pressure compressor **38** and a low pressure turbine **39**. The inner shaft **34** can be connected to the fan **36** through a geared architecture **45** to drive the fan **36** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **35** that interconnects a high pressure compressor **37** and a high pressure turbine **40**. In this embodiment, the inner shaft **34** and the outer shaft **35** are supported at various axial locations by bearing systems **31** positioned within the engine static structure **33**.

A combustor **42** is arranged between the high pressure compressor **37** and the high pressure turbine **40**. A mid-turbine frame **44** may be arranged generally between the high pressure turbine **40** and the low pressure turbine **39**. The mid-turbine frame **44** can support one or more bearing systems **31** of the turbine section **28**. The mid-turbine frame **44** may include one or more airfoils **46** that extend within the core flow path C.

The inner shaft **34** and the outer shaft **35** are concentric and rotate via the bearing systems **31** about the engine centerline longitudinal axis A, which is co-linear with their longitudinal axes. The core airflow is compressed by the low pressure compressor **38** and the high pressure compressor **37**, is mixed with fuel and burned in the combustor **42**, and is then expanded over the high pressure turbine **40** and the low pressure turbine **39**. The high pressure turbine **40** and the low pressure turbine **39** rotationally drive the respective high speed spool **32** and the low speed spool **30** in response to the expansion.

The pressure ratio of the low pressure turbine **39** can be pressure measured prior to the inlet of the low pressure turbine **39** as related to the pressure at the outlet of the low pressure turbine **39** and prior to an exhaust nozzle of the gas turbine engine **20**. In one non-limiting embodiment, the bypass ratio of the gas turbine engine **20** is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **38**, and the low pressure turbine **39** has a pressure ratio that is greater than about five (5:1). It should be understood, however, that the above parameters are only examples of one embodiment of a geared architecture engine and that the present disclosure is applicable to other gas turbine engines, including direct drive turbofans.

In this embodiment of the example gas turbine engine **20**, a significant amount of thrust is provided by the bypass flow path B due to the high bypass ratio. The fan section **22** of the gas turbine engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. This flight condition, with the gas turbine engine **20** at its best fuel consumption, is also known as bucket cruise Thrust Specific Fuel Consumption (TSFC). TSFC is an industry standard parameter of fuel consumption per unit of thrust.

Fan Pressure Ratio is the pressure ratio across a blade of the fan section **22** without the use of a Fan Exit Guide Vane system. The low Fan Pressure Ratio according to one non-limiting embodiment of the example gas turbine engine **20** is less than 1.45. Low Corrected Fan Tip Speed is the actual fan tip speed divided by an industry standard temperature correction of $[(T_{ram}° R)/(518.7° R)]^{0.5}$, where T_{ram} represents the ambient temperature in degrees Rankine. The Low Corrected Fan Tip Speed according to one non-limiting embodiment of the example gas turbine engine **20** is less than about 1150 fps (351 m/s).

Each of the compressor section **24** and the turbine section **28** may include alternating rows of rotor assemblies and vane assemblies (shown schematically) that carry airfoils that extend into the core flow path C. For example, the rotor assemblies can carry a plurality of rotating blades **25**, while each vane assembly can carry a plurality of vanes **27** that extend into the core flow path C. The blades **25** of the rotor assemblies create or extract energy (in the form of pressure) from the core airflow that is communicated through the gas turbine engine **20** along the core flow path C. The vanes **27** of the vane assemblies direct the core airflow to the blades **25** to either add or extract energy.

FIG. **1**B is a schematic illustration of a configuration of a combustion section of an engine. As shown, an engine **100** includes a combustor **102** defining a combustion chamber **104**. The combustor **102** includes an inlet **106** and an outlet **108** through which air may pass. The air may be supplied to the combustor **102** by a pre-diffuser **110**.

In the configuration shown in FIG. **1**B, air may be supplied from a compressor into an exit guide vane **112**. The exit guide vane **112** is configured to direct the airflow into the pre-diffuser **110**, which then directs the airflow toward the combustor **102**. The combustor **102** and the pre-diffuser **110** are separated by a shroud chamber **113** that contains the combustor **102** and includes an inner diameter branch **114** and an outer diameter branch **116**. As air enters the shroud chamber **113** a portion of the air may flow into the combustor inlet **106**, a portion may flow into the inner diameter branch **114**, and a portion may flow into the outer diameter branch **116**. The air from the inner diameter branch **114** and the outer diameter branch **116** may then enter the combustion chamber **104** by means of one or more nozzles, holes, apertures, etc. The air may then exit the combustion chamber **104** through the combustor outlet **108**. At the same time, fuel may be supplied into the combustion chamber **104** from a fuel injector **120** and a pilot nozzle **122**, which may be ignited within the combustion chamber **104**. The combustor **102** of the engine **100** may be housed within a shroud case **124** which may define the shroud chamber **113**.

The combustor **102** may be formed of one or more panels **126**, **128** that are mounted on one or more shells **130**. The panels **126**, **128** may be removably mounted to the shell **130** by one or more attachment mechanisms **132**. In some embodiments, the attachment mechanism **132** may be integrally formed with a respective panel **126**, **128**, although other configurations are possible. In some embodiments, the attachment mechanism **132** may be a bolt or other structure that may extend from the respective panel **126**, **128** through a receiving portion or aperture of the shell **130** such that the panel **126**, **128** may be attached to the shell **130** and held in place.

The panels **126**, **128** may include a plurality of cooling holes and/or apertures to enable fluid, such as gases, to flow from areas external to the combustion chamber **104** into the combustion chamber **104**. Impingement cooling may be provided from the shell-side of the panels **126**, **128**, with hot gases may be in contact with the combustion-side of the panels **126**, **128**. That is, hot gases may be in contact with a surface of the panels **126**, **128** that is facing the combustion chamber **104**.

First panels **126** may be configured about the inlet **106** of the combustor **102** and may be referred to as forward panels.

Second panels **128** may be positioned axially rearward and adjacent the first panels **126**, and may be referred to as aft panels. The first panels **126** and the second panels **128** are configured with a gap **134** formed between axially adjacent first panels **126** and second panels **128**. The gap **134** may be a circumferentially extending gap that extends about a circumference of the combustor **102**. A plurality of first panels **126** and second panels **128** may be attached and extend about an inner diameter of the combustor **102**, and a separate plurality of first and second panels **126**, **128** may be attached and extend about an outer diameter of the combustor **102**, as known in the art. As such, axially extending gaps may be formed between two circumferentially adjacent first panels **126** and between two circumferentially adjacent second panels **128**.

Turning now to FIG. **1**C, an illustration of a configuration of panels **126**, **128** installed within a combustor **102** is shown. The first panels **126** are installed to extend circumferentially about the combustion chamber **104** and form first axially extending gaps **136** between circumferentially adjacent first panels **126**. Similarly, the second panels **128** are installed to extend circumferentially about the combustion chamber **104** and second axially extending gaps **138** are formed between circumferentially adjacent second panels **128**. Moreover, as shown, the circumferentially extending gap **134** is shown between axially adjacent first and second panels **126**, **128**. Also shown in FIG. **1**C are the various cooling holes, apertures, and other fluid flow paths **140** that are formed in the surfaces of the panels **126**, **128**.

The gaps **134**, **136**, and **138** may enable movement and/or thermal expansion of various panels **126**, **128** such that room is provided to accommodate such movement and/or changes in shape or size of the panels **126**, **128**. Leakage or purge gases may flow into the combustion chamber **104** through the gaps **134**, **136**, and **138**. In some embodiments, cooling flow may be provided to an exterior side of the panels **126**, **128** to provide cooling to the combustor **102**. Flowing in the opposite direction, hot gas may ingest or flow from the combustion chamber **104** outward through the gaps **134**, **136**, and **138**. Hot gas injecting through the gaps **134**, **136**, and **138** may cause damage and/or wear on the material of the panels **126**, **128**.

Turning now to FIG. **2**, a side view of a circumferentially extending gap **234** formed between a first panel **226** and a second panel **228** is shown. As shown, the first panel **226** includes a first panel combustion chamber surface **226*a*** and a first panel rail **226*b*** extending from the combustion chamber surface **226*a***. As installed, the first panel combustion chamber surface **226*a*** defines a wall of a combustion chamber and the first panel rail **226*b*** extends outwardly and away from the combustion chamber toward a shell **230** to which the first panel **226** is mounted. As shown, an attachment mechanism **232** is configured to mount the first panel **226** to the shell **230**.

Similarly, the second panel **228** includes a second panel combustion chamber surface **228*a*** and a second panel rail **228*b*** extending from the combustion chamber surface **228*a***. As installed, the second panel combustion chamber surface **228*a*** defines a wall of a combustion chamber and the second panel rail **228*b*** extends outwardly and away from the combustion chamber toward a shell **230** to which the second panel **228** is mounted. As shown, an attachment mechanism **232** is configured to mount the second panel **228** to the shell **230**. The circumferentially extending gap **234** is formed between the first and second panels **226**, **228** and may be large because of the respective rails **226*b***, **228*b*** because it may be desirable to not have the panels **226**, **228** in contact with each other.

As shown, the rails **226*b***, **228*b*** are configured perpendicular to the respective combustion chamber surfaces **226*a***, **228*b***. That is, a first angle α where the first rail **226*b*** joins the first combustion chamber surface **226*a*** is equal to 90°. Similarly, a second angle β where the second rail **228*b*** joins the second combustion chamber surface **228*a*** is equal to 90°. Impingement cooling may be provided within the angle defined by the rails **226*b***, **228*b*** and the respective combustion chamber surfaces **226*a***, **228*b***. Leakage or purge gas may flow upward in FIG. **2**, moving from below the panels **226**, **228** and into a combustion chamber.

In a combustor configuration enabled by the panels **226**, **228** of FIG. **2**, the panels have different angles relative to an engine axis which may result in the circumferentially extending gap **234** at a junction between two axially adjacent panels (e.g., first panel **226** and second panel **228** axially adjacent thereto). Hot gas may entrain into the circumferentially extending gap **334** which may result in burn back oxidation distress on the first rail **226*b*** of the first panel **226** and the second rail **228*b*** of the second panel **228*b***.

Turning now to FIG. **3**, a schematic illustration of an embodiment in accordance with the present disclosure is shown. A first panel **326** is formed having a first combustion chamber surface **326*a*** and a first rail **326*b*** that are configured at a first angle α relative to the first combustion chamber surface **326*a***, with the first angle α being the angle between the first combustion chamber surface **326*a*** and the first rail **326*b***. A second panel **328** is formed having a second combustion chamber surface **328*a*** and a second rail **328*b*** that is configured at a second angle β relative to the second combustion chamber surface **328*a***, with the second angle β being the angle between the second combustion chamber surface **328*a*** and the second rail **328*b***.

In this embodiment, the first angle α and the second angle β are each less than 90°. This enables the first panel **326** and the second panel **328** to be positioned closer together and thus minimize the width of the circumferentially extending gap **334**. That is, each of the first rail **326*b*** and the second rail **328*b*** are angled with acute angles relative to the respective combustion chamber surfaces **326*a***, **328*a***.

In this embodiment, leakage flow, flowing from the exterior of a combustion chamber into a combustion chamber, i.e., upward through the circumferentially extending gap **334** in FIG. **3**, may be increased. That is, for example, because the distance between the first rail **326*b*** and the second rail **328*b*** decreases in a direction toward the respective combustion chamber surfaces **326*a***, **328*a*** (i.e., circumferentially extending gap **334** decreases in width), air flowing through the circumferentially extending gap **334** may accelerate and provide increased airflow to prevent impingement from the combustion chamber.

Turning now to FIG. **4**, a schematic illustration of another embodiment in accordance with the present disclosure is shown. A first panel **426** is formed having a first combustion chamber surface **426*a*** and a first rail **426*b*** that are configured at a first angle α relative to the first combustion chamber surface **426*a***, with the first angle α being the angle between the first combustion chamber surface **426*a*** and the first rail **426*b***. A second panel **428** is formed having a second combustion chamber surface **428*a*** and a second rail **428*b*** that is configured at a second angle β relative to the second combustion chamber surface **428*a***, with the second angle β being the angle between the second combustion chamber surface **428*a*** and the second rail **428*b***.

In this embodiment, the first angle α is set at 90° and the second angle β is an acute angle. Although shown with the first rail **426***a* and the second rail **426***b* as parallel, this is merely one embodiment, and the present disclosure is not limited to the two rails being parallel. The adjusted angles enable the first panel **426** and the second panel **428** to be positioned close together and thus minimize the width of the circumferentially extending gap **434**. That is, by angling the second angle β with an acute angle the two panels **426**, **428** may be positioned close together.

Turning now to FIG. **5**, a schematic illustration of another embodiment in accordance with the present disclosure is shown. A first panel **526** is formed having a first combustion chamber surface **526***a* and a first rail **526***b* that are configured at a first angle α relative to the first combustion chamber surface **526***a*, with the first angle α being the angle between the first combustion chamber surface **526***a* and the first rail **526***b*. A second panel **528** is formed having a second combustion chamber surface **528***a* and a second rail **528***b* that is configured at a second angle β relative to the second combustion chamber surface **528***a*, with the second angle β being the angle between the second combustion chamber surface **528***a* and the second rail **528***b*.

In this embodiment, the first angle α is an acute angle and the second angle β is set at 90°. Although shown with the first rail **526***a* and the second rail **526***b* as parallel, this is merely one embodiment, and the present disclosure is not limited to the two rails being parallel. The adjusted angles enable the first panel **526** and the second panel **528** to be positioned close together and thus minimize the width of the circumferentially extending gap **534**. That is, by angling the first angle α with an acute angle the two panels **526**, **528** may be positioned close together.

Advantageously, embodiments described herein provide panels in a combustor of a gas turbine engine having improved leakage flow such that impingement flow may be minimized and/or prevented through panels of the combustor. Further, advantageously, embodiments provided herein may minimize a gap between adjacent panels of a combustor while maintaining a gap having a desired width or distance to enable thermal expansion and/or moving of adjacent panels relative to each other. Moreover, a more effective purge mechanism may be provided for a leakage flow of the panels of the combustor.

While the present disclosure has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the present disclosure is not limited to such disclosed embodiments. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions, combinations, sub-combinations, or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments.

For example, although various angles and configurations are provided herein, those of skill in the art will appreciate that other angles may be employed without departing from the scope of the present disclosure. For example, in the above described embodiments, when one of the first angle or the second angle is set to 90° and the other is set to an acute angle, those of skill in the art will appreciate that the larger angle can be greater than 90°, with the other angle being even more acute than that shown. Further, even though shown and described with embodiments such that the first and second rails are parallel, those of skill in the art will appreciate that even with one rail set to 90°, the two rails are not required to be parallel, as any non-90° angle may be employed without departing from the scope of the present disclosure.

Further, for example, although described with respect to the circumferentially extending gap of the combustor, those of skill in the art will appreciate that rails of panels that form axially extending gaps may employ angles as described herein.

Accordingly, the present disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

What is claimed is:

1. A combustor of a gas turbine engine comprising:

a combustor shell having an interior surface and defining a combustion chamber having an axial length;

at least one first panel mounted to the interior surface at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail joins the first combustion chamber surface at a first angle α; and

at least one second panel mounted to the interior surface at a second position and axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail joins the second combustion chamber surface at a second angle β,

wherein the first rail and the second rail are proximal to each other and define a circumferentially extending gap therebetween, and

wherein at least one of the first angle α or the second angle β is an acute angle; and

wherein

the at least one first panel comprises a plurality of first panels, wherein the plurality of first panels define a first axially extending gap between two circumferentially adjacent first panels, and each first panel of the two circumferentially adjacent first panels have respective axially extending rails that extend from their respective first combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent first panels is configured at an acute angle relative to the first combustion chamber surface of the respective first panel the one rail extends from; and/or

the at least one second panel comprises a plurality of second panels, wherein the plurality of second panels define a second axially extending gap between two circumferentially adjacent second panels, and each second panel of the two circumferentially adjacent second panels have respective axially extending rails that extend from their respective second combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent second panels is configured at an acute angle relative to the second combustion chamber surface of the respective second panel the one rail extends from.

2. The combustor of claim **1**, wherein both of the first angle α and the second angle β are acute angles.

3. The combustor of claim **1**, wherein the first rail and the second rail are parallel to each other.

4. The combustor of claim 1, wherein the other of the at least one of the first angle α and the second angle β is configured at a 90° angle.

5. A gas turbine engine comprising:

a combustor including a combustor shell having an interior surface and defining a combustion chamber having an axial length;

at least one first panel mounted to the interior surface at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail joins the first combustion chamber surface at a first angle α; and

at least one second panel mounted to the interior surface at a second position and axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail joins the second combustion chamber surface at a second angle β,

wherein the first rail and the second rail are proximal to each other and define a circumferentially extending gap therebetween, and

wherein at least one of the first angle α or the second angle β is an acute angle,

wherein:

the at least one first panel comprises a plurality of first panels, wherein the plurality of first panels define a first axially extending gap between two circumferentially adjacent first panels, and each first panel of the two circumferentially adjacent first panels have respective axially extending rails that extend from their respective first combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent first panels is configured at an acute angle relative to the first combustion chamber surface of the respective first panel the one rail extends from; and/or

the at least one second panel comprises a plurality of second panels, wherein the plurality of second panels define a second axially extending gap between two circumferentially adjacent second panels, and each second panel of the two circumferentially adjacent second panels have respective axially extending rails that extend from their respective second combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent second panels is configured at an acute angle relative to the second combustion chamber surface of the respective second panel the one rail extends from.

6. The gas turbine engine of claim 5, wherein both of the first angle α and the second angle β are acute angles.

7. The gas turbine engine of claim 5, wherein the first rail and the second rail are parallel to each other.

8. The gas turbine engine of claim 5, wherein the other of the at least one of the first angle α and the second angle β is configured at a 90° angle.

9. A method of manufacturing a combustor of a gas turbine engine comprising:

mounting at least one first panel to an interior surface of a combustion chamber shell at a first position, the at least one first panel having a first combustion chamber surface and a first rail extending from the first combustion chamber surface toward the interior surface of the combustor shell, the first rail joins the first combustion chamber surface at a first angle α; and

mounting at least one second panel to the interior surface at a second position axially adjacent to the at least one first panel, the at least one second panel having a second combustion chamber surface and a second rail extending from the second combustion chamber surface toward the interior surface of the combustor shell, the second rail joins the second combustion chamber surface at a second angle β,

wherein the first rail and the second rail are proximal to each other and define a circumferentially extending gap therebetween, and wherein at least one of the first angle α or the second angle β is an acute angle,

wherein:

the at least one first panel comprises a plurality of first panels, wherein the plurality of first panels define a first axially extending gap between two circumferentially adjacent first panels, and each first panel of the two circumferentially adjacent first panels have respective axially extending rails that extend from their respective first combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent first panels is configured at an acute angle relative to the first combustion chamber surface of the respective first panel the one rail extends from; and/or

the at least one second panel comprises a plurality of second panels, wherein the plurality of second panels define a second axially extending gap between two circumferentially adjacent second panels, and each second panel of the two circumferentially adjacent second panels have respective axially extending rails that extend from their respective second combustion chamber surfaces toward the interior surface, wherein one rail of the respective axially extending rails of the two circumferentially adjacent second panels is configured at an acute angle relative to the second combustion chamber surface of the respective second panel the one rail extends from.

10. The method of claim 9, wherein both of the first angle α and the second angle β are acute angles.

11. The method of claim 9, wherein the first rail and the second rail are parallel to each other.

12. The method of claim 9, wherein the other of the at least one of the first angle α and the second angle β is configured at a 90° angle.

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